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Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks

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Abstract

A wavelength switched optical network (WSON) requires that certain key information elements are made available to facilitate path computation and the establishment of label switching paths (LSPs). The information model described in "Routing and Wavelength Assignment Information for Wavelength Switched Optical Networks" shows what information is required at specific points in the WSON.

The information may be used in Generalized Multiprotocol Label Switching (GMPLS) signaling protocols, and may be distributed by GMPLS routing protocols. Other distribution mechanisms (for example, XML-based protocols) may also be used.

This document provides efficient, protocol-agnostic encodings for the information elements necessary to operate a WSON. It is intended that protocol-specific documents will reference this memo to describe how information is carried for specific uses.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119].

Table of Contents

1. Introduction...3
   1.1. Revision History..4
      1.1.1. Changes from 00 draft................................4
2. Terminology..4
3. Encoding of WSON Information: Sub-TLVs.........................5
   3.1. Link Set Sub-TLV..5
   3.2. Connectivity Matrix Sub-TLV...............................6
   3.3. Wavelength Information Encoding..........................10
   3.4. Wavelength Set Sub-TLV...................................11
      3.4.1. Inclusive/Exclusive Wavelength Lists................11
      3.4.2. Inclusive/Exclusive Wavelength Ranges...............12

3.4.3. Bitmap Wavelength Set................................12
3.5. Port Wavelength Restriction sub-TLV......................14
3.6. Wavelength Converter Set Sub-TLV.........................15
3.7. Wavelength Converter Accessibility Sub-TLV...............16
3.8. Wavelength Conversion Range Sub-TLV......................19
3.9. WC Usage State Sub-TLV...................................21
4. Composite TLVs...22
4.1. WSON Node TLV..22
4.2. WSON Link TLV..23
4.3. WSON Dynamic Link TLV....................................24
4.4. WSON Dynamic Node TLV....................................24
5. Security Considerations....................................24
6. IANA Considerations..24
7. Acknowledgments..25
8. References...26
8.1. Normative References.....................................26
8.2. Informative References...................................26
9. Contributors...28
Authors' Addresses..28
Intellectual Property Statement...............................29
Disclaimer of Validity..30

1. Introduction

A Wavelength Switched Optical Network (WSON) is a Wavelength Division Multiplexing (WDM) optical network in which switching is performed selectively based on the center wavelength of an optical signal.

[WSON-Frame] describes a framework for Generalized Multiprotocol Label Switching (GMPLS) and Path Computation Element (PCE) control of a WSON. Based on this framework, [WSON-Info] describes an information model that specifies what information is needed at various points in a WSON in order to compute paths and establish Label Switched Paths (LSPs).

This document provides efficient encodings of information needed by the routing and wavelength assignment (RWA) process in a WSON. Such encodings can be used to extend GMPLS signaling and routing protocols. In addition these encodings could be used by other mechanisms to convey this same information to a path computation element (PCE). Note that since these encodings are relatively efficient they can provide more accurate analysis of the control plane communications/processing load for WSONs looking to utilize a GMPLS control plane.

1.1. Revision History

1.1.1. Changes from 00 draft

Edits to make consistent with update to [Otani], i.e., removal of sign bit.

Clarification of TBD on connection matrix type and possibly numbering.

New sections for wavelength converter pool encoding: Wavelength Converter Set Sub-TLV, Wavelength Converter Accessibility Sub-TLV, Wavelength Conversion Range Sub-TLV, WC Usage State Sub-TLV.

Added optional wavelength converter pool TLVs to the composite node TLV.

2. Terminology

CWDM: Coarse Wavelength Division Multiplexing.

DWDM: Dense Wavelength Division Multiplexing.

FOADM: Fixed Optical Add/Drop Multiplexer.

ROADM: Reconfigurable Optical Add/Drop Multiplexer. A reduced port count wavelength selective switching element featuring ingress and egress line side ports as well as add/drop side ports.

RWA: Routing and Wavelength Assignment.

Wavelength Conversion. The process of converting an information bearing optical signal centered at a given wavelength to one with "equivalent" content centered at a different wavelength. Wavelength conversion can be implemented via an optical-electronic-optical (OEO) process or via a strictly optical process.

WDM: Wavelength Division Multiplexing.

Wavelength Switched Optical Network (WSON): A WDM based optical network in which switching is performed selectively based on the center wavelength of an optical signal.

3. Encoding of WSON Information: Sub-TLVs

A TLV encoding of the high level WSON information model [WSON-Info] is given in the following sections. This encoding is designed to be suitable for use in the GMPLS routing protocols OSPF [RFC4203] and IS-IS [RFC5307] and in the PCE protocol PCEP [PCEP]. Note that the information distributed in [RFC4203] and [RFC5307] is arranged via the nesting of sub-TLVs within TLVs and this document makes use of such constructs.

3.1. Link Set Sub-TLV

We will frequently need to describe properties of groups of links. To do so efficiently we can make use of a link set concept similar to the label set concept of [RFC3471]. All links will be denoted by their local link identifier as defined an used in [RFC4202], [RFC4203], and [RFC5307].

The information carried in a Link Set is defined by:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Action     |Dir|  Format   |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Link Identifier 1                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                               :                               :
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Link Identifier N                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action: 8 bits

0 - Inclusive List

Indicates that the TLV contains one or more link elements that are included in the Link Set.

2 - Inclusive Range

Indicates that the TLV contains a range of links. The object/TLV contains two link elements. The first element indicates the start of the range. The second element indicates the end of the range. A value

of zero indicates that there is no bound on the corresponding portion of the range.

Dir: Directionality of the Link Set (2 bits)

0 -- bidirectional

1 -- incoming

2 -- outgoing

In optical networks we think in terms of unidirectional as well as bidirectional links. For example, wavelength restrictions or connectivity may be different for an ingress port, than for its "companion" egress port if one exists. Note that "interfaces" such as those discussed in the Interfaces MIB [RFC2863] are assumed to be bidirectional. This also applies to the links advertised in various link state routing protocols.

Format: The format of the link identifier (6 bits)

0 -- Link Local Identifier

Others TBD.

Note that all link identifiers in the same list must be of the same type.

Reserved: 16 bits

This field is reserved. It MUST be set to zero on transmission and MUST be ignored on receipt.

Link Identifier:

The link identifier represents the port which is being described either for connectivity or wavelength restrictions. This can be the link local identifier of [RFC4202], GMPLS routing, [RFC4203] GMPLS OSPF routing, and [RFC5307] IS-IS GMPLS routing. The use of the link local identifier format can result in more compact WSON encodings when the assignments are done in a reasonable fashion.

3.2. Connectivity Matrix Sub-TLV

The switch and fixed connectivity matrices of [WSON-Info] can be compactly represented in terms of a minimal list of ingress and

egress port set pairs that have mutual connectivity. As described in [Switch] such a minimal list representation leads naturally to a graph representation for path computation purposes that involves the fewest additional nodes and links.

A TLV encoding of this list of link set pairs is:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Connectivity  |               Reserved                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Link Set A #1                         |
   :                               :                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Link Set B #1                         :
   :                               :                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Additional Link set pairs as needed     |
   :                     to specify connectivity                   :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Connectivity = 0 if the device is fixed

1 if the device is switched(e.g., ROADM/OXC)

TBD: Should we just have two sub-TLVs one for fixed one for switched, or should we number matrices for a more general solution.

Example:

Suppose we have a typical 2-degree 40 channel ROADM. In addition to its two line side ports it has 80 add and 80 drop ports. The picture below illustrates how a typical 2-degree ROADM system that works with bi-directional fiber pairs is a highly asymmetrical system composed of two unidirectional ROADM subsystems.

```
                         (Tributary) Ports #3-#42
                     Ingress added to    Egress dropped from
                     West Line Egress    East Line Ingress
                           vvvvv          ^^^^^
                          | |||.|        | |||.|
                    +-----| |||.|--------| |||.|------+
                    |    +----------------------+     |
                    |    |                      |     |
         Egress     |    | Unidirectional ROADM |     |    Ingress
   -----------------+    |                      |     +--------------
   <====================|                      |===================<
   -----------------+    +----------------------+     +--------------
                    |                                 |
         Port #1    |                                 |   Port #2
   (West Line Side) |                                 |(East Line Side)
   -----------------+    +----------------------+     +--------------
   >====================|                      |===================>
   -----------------+    | Unidirectional ROADM |     +--------------
         Ingress    |    |                      |     |    Egress
                    |    |              _       |     |
                    |    +----------------------+     |
                    +-----| |||.|--------| |||.|------+
                          | |||.|        | |||.|
                           vvvvv          ^^^^^
                     (Tributary) Ports #43-#82
                Egress dropped from    Ingress added to
                West Line ingress      East Line egress
```

Referring to the figure we see that the ingress direction of ports #3-#42 (add ports) can only connect to the egress on port #1. While the ingress side of port #2 (line side) can only connect to the egress on ports #3-#42 (drop) and to the egress on port #1 (pass through). Similarly, the ingress direction of ports #43-#82 can only connect to the egress on port #2 (line). While the ingress direction of port #1 can only connect to the egress on ports #43-#82 (drop) or port #2 (pass through). We can now represent this potential connectivity matrix as follows. This representation uses only 30 32-bit words.

```
       0                   1                   2                   3
       0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |    Conn = 1   |                  Reserved                     |1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Note: adds to line
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=2     |0 1|0 0 0 0 0 0|Reserved(Note:inclusive range) |2
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #3                |3
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #42               |4
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |1 0|0 0 0 0 0 0|Reserved (Note:inclusive list) |5
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #1                |6
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to drops
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |0 1|0 0 0 0 0 0|Reserved (Note:inclusive list) |7
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #2                |8
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=2     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive range)|9
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #3                |10
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #42               |11
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to line
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |0 1|0 0 0 0 0 0|Reserved (Note:inclusive list) |12
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #2                |13
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive range)|14
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #1                |15
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                             Note: adds to line
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=2     |0 1|0 0 0 0 0 0|Reserved(Note:inclusive range) |16
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #42               |17
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
     |                     Link Local Identifier = #82               |18
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |1 0|0 0 0 0 0 0|Reserved (Note:inclusive list) |19
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #2                |20
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to drops
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |0 1|0 0 0 0 0 0|Reserved (Note:inclusive list) |21
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #1                |22
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=2     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive range)|23
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #43               |24
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #82               |25
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to line
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |0 1|0 0 0 0 0 0|Reserved (Note:inclusive list) |26
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #1                |27
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Action=0     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive range)|28
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Link Local Identifier = #2                |30
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

3.3. Wavelength Information Encoding

This document makes frequent use of the lambda label format defined in [Otani] shown below strictly for reference purposes:

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |  Reserved       |               n               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

Grid is used to indicate which ITU-T grid specification is being used.

C.S. = Channel spacing used in a DWDM system, i.e., with a ITU-T G.694.1 grid.

n = Used to specify the frequency as 193.1THz +/- n*(channel spacing) and n is an integer to take either a negative, zero or a positive value.

3.4. Wavelength Set Sub-TLV

Wavelength sets come up frequently in WSONs to describe the range of a laser transmitter, the wavelength restrictions on ROADM ports, or the availability of wavelengths on a DWDM link. The general format for a wavelength set is given below. This format uses the Action concept from [RFC3471] with an additional Action to define a "bit map" type of label set. Note that the second 32 bit field is a lambda label in the previously defined format. This provides important information on the WDM grid type and channel spacing that will be used in the compact encodings listed.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Action        |   Reserved     |    Num Wavelengths            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |    Reserved      |  n  for lowest frequency      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Additional fields as necessary per action                  |
   |
```

Action:

0 - Inclusive List

1 - Exclusive List

2 - Inclusive Range

3 - Exclusive Range

4 - Bitmap Set

3.4.1. Inclusive/Exclusive Wavelength Lists

In the case of the inclusive/exclusive lists the wavelength set format is given by:

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Action=0 or 1  | Reserved      |      Num Wavelengths          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved   |    n  for lowest frequency    |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |    n2                         |          n3                   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |    nm                         |                                |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Num Wavelengths tells us the number of wavelength in this inclusive or exclusive list this does not include the initial wavelength in the list hence if the number of wavelengths is odd then zero padding of the last half word is required.

3.4.2. Inclusive/Exclusive Wavelength Ranges

In the case of inclusive/exclusive ranges the wavelength set format is given by:

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Action=2 or 3  | Reserved      |      Num Wavelengths          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |    Reserved     |      n  for lowest frequency  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case Num Wavelengths specifies the number of wavelengths in the range starting at the given wavelength and incrementing the Num Wavelengths number of channel spacing up in frequency.

3.4.3. Bitmap Wavelength Set

In the case of Action = 4, the bitmap the wavelength set format is given by:

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Action = 4    | Reserved      |      Num Wavelengths          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |Grid |  C.S. |    Reserved   |      n  for lowest frequency    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Bit Map Word #1 (Lowest frequency channels)                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    :                                                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Bit Map Word #N (Highest frequency channels)               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Num Wavelengths in this case tells us the number of wavelengths represented by the bit map. Each bit in the bit map represents a particular frequency with a value of 1/0 indicating whether the frequency is in the set or not. Bit position zero represents the lowest frequency, while each succeeding bit position represents the next frequency a channel spacing (C.S.) above the previous.

The size of the bit map is clearly Num Wavelengths bits, but the bit map is made up to a full multiple of 32 bits so that the TLV is a multiple of four bytes. Bits that do not represent wavelengths (i.e., those in positions (Num Wavelengths - 1) and beyond) SHOULD be set to zero and MUST be ignored.

Example:

A 40 channel C-Band DWDM system with 100GHz spacing with lowest frequency 192.0THz (1561.4nm) and highest frequency 195.9THz (1530.3nm). These frequencies correspond to n = -11, and n = 28 respectively. Now suppose the following channels are available:

Frequency (THz)	n Value	bit map position
192.0	-11	0
192.5	-6	5
193.1	0	11
193.9	8	19
194.0	9	20
195.2	21	32
195.8	27	38

With the Grid value set to indicate an ITU-T G.694.1 DWDM grid, C.S. set to indicate 100GHz this lambda bit map set would then be encoded as follows:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Action = 4    | Reserved      |    Num Wavelengths = 40       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |      Reserved   | n  for lowest frequency = -11 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |1 0 0 0 0 0 1 0|   Not used in 40 Channel system (all zeros)   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

3.5. Port Wavelength Restriction sub-TLV

The port wavelength restriction of [WSON-Info] can be encoded as a sub-TLV as follows.

```
      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |RestrictionKind|T|  Reserved   |     MaxNumChannels            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                  --Wavelength Set--
     | Action        |   Reserved    |    Num Wavelengths            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |    Reserved     |  n  for lowest frequency      |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |     Additional fields as necessary per action                 |
     |                                                               |
```

RestrictionKind can take the following values and meanings:

0:   Simple wavelength selective restriction. Max number of channels indicates the number of wavelengths permitted on the port and the accompanying wavelength set indicates the permitted values.

1:   Waveband device with a tunable center frequency and passband. In this case the maximum number of channels indicates the maximum width of the waveband in terms of the channels spacing given in the wavelength set. The corresponding wavelength set is used to indicate the overall tuning range. Specific center frequency tuning information can be obtained from dynamic channel in use information. It is assumed that both center frequency and bandwidth (Q) tuning can be done without causing faults in existing signals.

Values for T include:

0 == Use with a fixed connectivity matrix

1 == Use with a switched connectivity matrix

TBD: Should we just have two flavors of sub-TLV, or if we add numbering to identify matrices we could add a number field here (using currently reserved bits) to associate the constraints with the right matrix.

3.6. Wavelength Converter Set Sub-TLV

A WSON node may include a set of wavelength converters (WC). We need to describe the WC list which a node supports. This can be done via a WC Set concept similar to the label set concept of [RFC3471].

The information carried in a WC set is defined by:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    Action     |             Reserved                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     WC Identifier 1           |        WC Identifier 2        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   :                               :                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     WC Identifier n-1         |        WC Identifier n        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action: 8 bits

0 - Inclusive List

Indicates that the TLV contains one or more WC elements that are included in the list.

2 - Inclusive Range

Indicates that the TLV contains a range of WCs. The object/TLV contains two WC elements. The first element indicates the start of the range. The second element indicates the end of the range. A value of zero indicates that there is no bound on the corresponding portion of the range.

Reserved: 24 bits

This field is reserved. It MUST be set to zero on transmission and MUST be ignored on receipt.

WC Identifier:

The WC identifier represents the ID of the wavelength convertor which is a 16 bit integer.

3.7. Wavelength Converter Accessibility Sub-TLV

A WSON node may include wavelength converters. As described in [WSON-Info], we should give the accessibility of a wavelength converter to convert from a given ingress wavelength on a particular ingress port to a desired egress wavelength on a particular egress port. Before this, we need to describe the accessibility of a wavelength

converter to convert form a given ingress port to a desired egress port. This information can be determined by the PoolIngressMatrix and PoolEgressMatrix of [WSON-Info]. We can use a set of links (Link set) followed by a set of WCs (WC set) to represent that this link set can access this WC set. We use a set of WC (WC set) followed by a set of links (Link set) to represent that this WC set can access this link set.

The wavelength converter accessibility TLV is defined by:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Num In Pairs  |           Reserved                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Ingress Link Set A #1                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           WC  Set A #1                        |
:                               :                               :
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Additional Link set and WC set pairs as needed to     |
:                     specify PoolIngressMatrix                 :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    WC Set B #1 (for egress connectivity)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Egress link Set B #1                    |
:                               :                               :
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Additional WC set and egress link set pairs           |
:               as needed to specify PoolEgressMatrix           :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Num_In_Pairs tells us the number of ingress link and WC set pairs. TBD: if link sets are identified in their own sub-TLVs and similarly for WC sets then we may not need this field.

Example:

Figure 1 shows a wavelength converter pool architecture know as "shared per fiber". In this case the ingress and egress pool matrices are simply:

```
              +-----+       +-----+
              | 1 1 |       | 1 0 |
          WI =|     |,  WE =|     |
              | 1 1 |       | 0 1 |
              +-----+       +-----+


                    +-----------+                      +------+
                    |           |--------------------->|      |
                    |           |--------------------->|  C   |
              /|    |           |--------------------->|  o   | E1
        I1   /D+--->|           |--------------------->|  m   |
            + e+--->|           |                      |  b   |========>
   ========>| M|    |  Optical  |    +-----------+     |  i   | Port #3
   Port #1  + u+--->|   Switch  |    |  WC Pool  |     |  n   |
             \x+--->|           |    |  +-----+  |     |  e   |
              \|    |           +----+->|WC #1|--+---->|  r   |
                    |           |    |  +-----+  |     +------+
                    |           |    |           |     +------+
              /|    |           |    |  +-----+  |     |      |
        I2   /D+--->|           +----+->|WC #2|--+---->|  C   | E2
            + e+--->|           |    |  +-----+  |     |  o   |
   ========>| M|    |           |    +-----------+     |  m   |========>
   Port #2  + u+--->|           |                      |  b   | Port #4
             \x+--->|           |--------------------->|  i   |
              \|    |           |--------------------->|  n   |
                    |           |--------------------->|  e   |
                    |           |--------------------->|  r   |
                    +-----------+                      +------+
```

Figure 1 An optical switch featuring a shared per fiber wavelength
converter pool architecture.

This wavelength converter pool can be encoded as follows:

```
       0                   1                   2                   3
       0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      | Num In Pairs=1|                   Reserved                    |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                 Note: I1,I2 can connect to either WC1 or WC2
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |0 1|0 0 0 0 0 0|Reserved(Note: inclusive list) |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Link Local Identifier = #1               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Link Local Identifier = #2               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |          Reserved(Note: inclusive WC list)    |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |           WC ID = #1          |       WC ID = #2              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: WC1 can only connect to E1
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |       Reserved(Note: inclusive list)          |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |           WC ID = #1          |       zero padding            |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive list) |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Link Local Identifier = #3               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: WC2 can only connect to E2
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |       Reserved(Note: inclusive WC list)       |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |           WC ID = #2          |       zero padding            |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  Action=0     |1 0|0 0 0 0 0 0|Reserved(Note: inclusive list) |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Link Local Identifier = #4               |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

3.8. Wavelength Conversion Range Sub-TLV

Since not all wavelengths can necessarily reach all the converters or the converters may have limited input wavelength range we can have a

set of ingress wavelength constraints for each wavelength converter. In addition, we also can have output wavelength constraints.

The information carried in a wavelength conversion range Sub-TLV is defined by:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Reserved                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     WC Set #1                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Input Wavelength Set #1                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Output Wavelength Set #1                   |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Additional WC Wavelength constraint set pairs as needed  |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

WC Set:

Indicates the WCs which have the same conversion range. We group the WCs which have the same conversion range to WC Set followed by the input and output wavelength range for reducing the data size.

The format of WC Set is consistent with the encoding of "WC Set Sub-TLV".

Input Wavelength Set:

Indicates the wavelength input range of WC(s).

The format of Input Wavelength Set is consistent with the encoding of "Wavelength Set Sub-TLV".

Output Wavelength Set:

Indicates the wavelength output range of WC(s).

The format of Output Wavelength Set is consistent with the encoding of "Wavelength Set Sub-TLV".

Example:

We give an example based on figure 1 about how to represent the wavelength conversion range of wavelength converters. Suppose the wavelength range of input and output of WC1 and WC2 are {L1, L2, L3, L4}:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Reserved                                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Note: WC Set
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Action=0     |0 1|      Reserved(Note: inclusive list)       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           WC ID = #1          |       WC ID = #2              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Note: wavelength input range
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Action = 2    |   Reserved    |    Num Wavelengths = 4        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |     Reserved    |  n for lowest frequency = 1   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Note: wavelength output range
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Action = 2    |   Reserved    |    Num Wavelengths = 4        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |     Reserved    |  n for lowest frequency = 1   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

3.9. WC Usage State Sub-TLV

WC Usage state dependents upon whether the wavelength converter in the pool is in use. This is the only state kept in the converter pool model.

```
       0                   1                   2                   3
       0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                     WC Set sub-TLV                          |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                     WC Usage state                            |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                     ......            |      Padded bits      |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

WC Usage state can be encoded by bit map. The bits indicate the usage state of the wavelength convertors which is being described in the WC Set sub-TLV.

WC Usage state: : Variable Length.

Each bit indicates the usage status of one WC. The sequence of the bit map is consistent with the WC list in this TLV.

Padded bit: Variable Length

It is used to pad the bit to make the whole number of bits in bitmap be the time of 32. Padded bit MUST be set to 0.

4. Composite TLVs

The Four composite TLVs in the following sections are based on the four high level information bundles of [WSON-Info].

4.1. WSON Node TLV

The WSON Node TLV consists of the following ordered list of sub-TLVs:

<Node_Info> ::= <Node_ID> [<SwitchedConnectivityMatrix>] [<FixedConnectivityMatrix>], [<SRNG>] [<WavelengthConverterPool>]

o Node ID (This will be derived from standard IETF node identifiers)

o Switch Connectivity Matrix - (optional) This is a connectivity matrix sub-TLV with the connectivity type set to "switched" (conn = 1)

o Fixed Connectivity Matrix - (optional) This is a connectivity matrix sub-TLV with the connectivity type set to "fixed" (conn = 0).

- o Shared Risk Node Group - (optional) Format TBD (note that current GMPLS SRLG encoding is general enough to include SRNG information).

- o Wavelength Converter Pool TLVs- (optional) Wavelength Converter Set Sub-TLV, Wavelength Converter Accessibility Sub-TLV, and Wavelength Conversion Range Sub-TLV.

4.2. WSON Link TLV

Note that a number of sub-TLVs for links have already been defined and it is for further study if we can or should reuse any of those sub-TLVs in our encoding. Note that for a system already employing GMPLS based routing the existing encodings and transport mechanisms should be used and the information does not need to appear twice.

```
<LinkInfo> ::=  <LinkID> [<AdministrativeGroup>] [<InterfaceCapDesc>]
[<Protection>] [<SRLG>]... [<TrafficEngineeringMetric>]
[<MaximumBandwidthPerChannel>] <[SwitchedPortWavelengthRestriction>]
[<FixedPortWavelengthRestriction>]
```

- o Link Identifier - Need to double check on this with RFC4203 (required).

- o Administrative Group - (optional) Standard sub-TLV type 9, RFC3630.

- o Interface Switching Capability Descriptor - Standard sub-TLV type 15, RFC4203.

- o Protection - (optional) Standard sub-TLV type 15, RFC4203.

- o Shared Risk Link Group - (optional) Standard sub-TLV 16, RFC4203.

- o Traffic Engineering Metric - (optional) Standard sub-TLV type 5, RFC3630.

- o Maximum Bandwidth per Channel - TBD.

- o Switched Port Wavelength Restriction - (optional) The port wavelength restriction sub-TLV with T = 1.

- o Fixed Port Wavelength Restriction - (optional) The port wavelength restriction sub-TLV with T = 0.

4.3. WSON Dynamic Link TLV

<DynamicLinkInfo> ::= <LinkID> <AvailableWavelengths> [<SharedBackupWavelengths>]

Where

<LinkID> ::= <LocalLinkID> <LocalNodeID> <RemoteLinkID> <RemoteNodeID>

- Available Wavelengths - A wavelength set sub-TLV used to indicate which wavelengths are available on this link.

- Shared Backup Wavelengths - (optional) A wavelength set sub-TLV used to indicate which wavelengths on this link are currently used for shared backup protection (and hence can possibly be reused).

4.4. WSON Dynamic Node TLV

<NodeInfoDynamic> ::= <NodeID> [<WCPoolState>]

- Node ID - Format TBD.

- Wavelength Converter Pool Status - (optional) This is the WC Usage state sub-TLV.

Note that currently the only dynamic information modeled with a node is associated with the status of the wavelength converter pool.

5. Security Considerations

This document defines protocol-independent encodings for WSON information and does not introduce any security issues.

However, other documents that make use of these encodings within protocol extensions need to consider the issues and risks associated with, inspection, interception, modification, or spoofing of any of this information. It is expected that any such documents will describe the necessary security measures to provide adequate protection.

6. IANA Considerations

TBD. Once our approach is finalized we may need identifiers for the various TLVs and sub-TLVs.

7. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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